

Challenges for Robust Ocean Data Assimilation



Alicia Karspeck, Steve Yeager, **Tim Hoar**, Kevin Raeder,
Nancy Collins, Jeffrey Anderson, and Gokhan Danabasoglu
National Center for Atmospheric Research

Outline

1. Overview of DART and CESM/POP (1 slide)
2. Description of initialization problem
3. Description of boundary currents problem
4. Solutions/Directions/Delusions ...

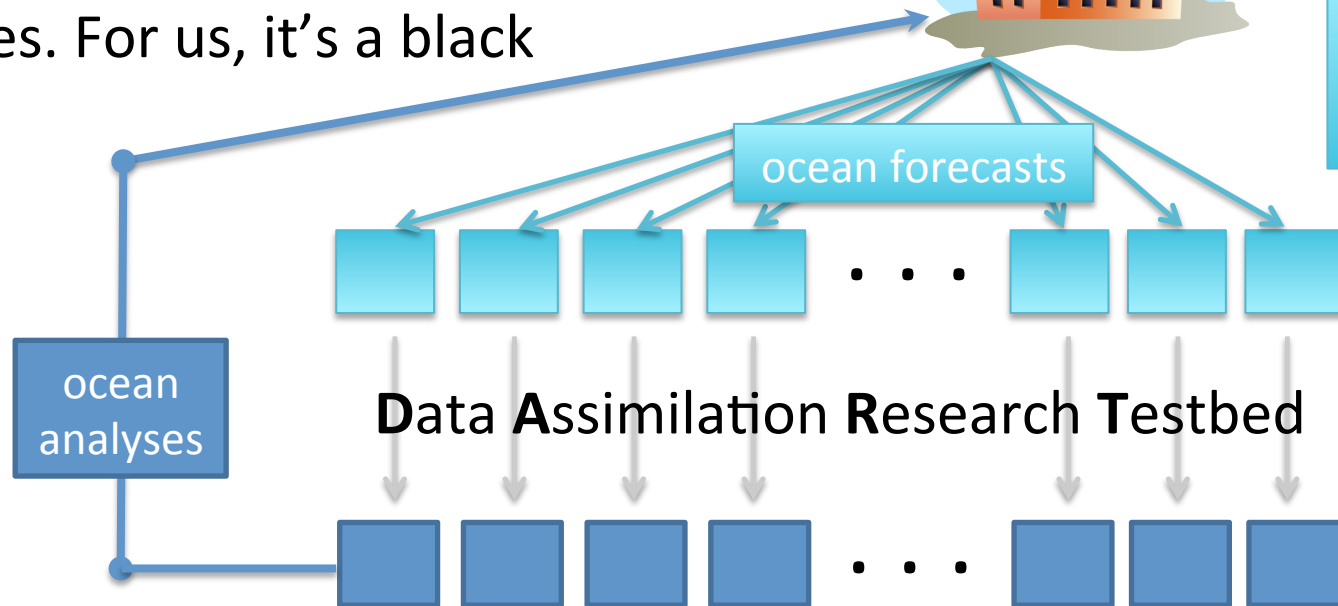
Overview

CESM has lots of model components and provides **multiple instances** of model states. For us, it's a black box.

Community
Earth
System
Model



Parallel
Ocean
Program



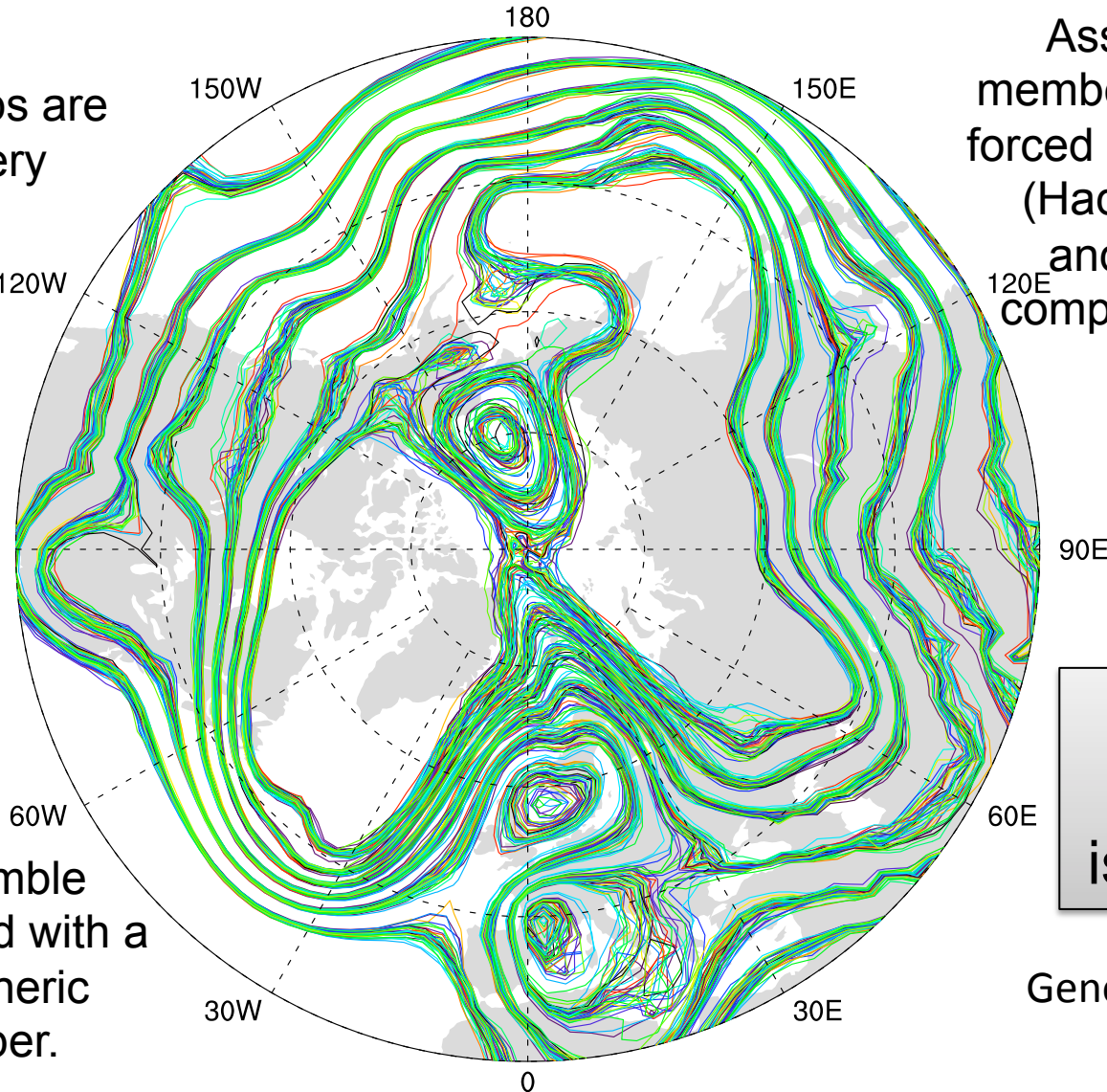
Given this **ensemble** and observations, DART determines increments for the model states, the model states get updated, and the ensemble is fed back to CESM to be advanced to the next desired time.

Atmospheric Reanalysis

O(1 million) atmospheric obs are assimilated every day.

Assimilation uses 80 members of 2° FV CAM forced by a single ocean (Hadley + NCEP-OI2) and produces a very competitive reanalysis.

500 hPa GPH
Feb 17 2003



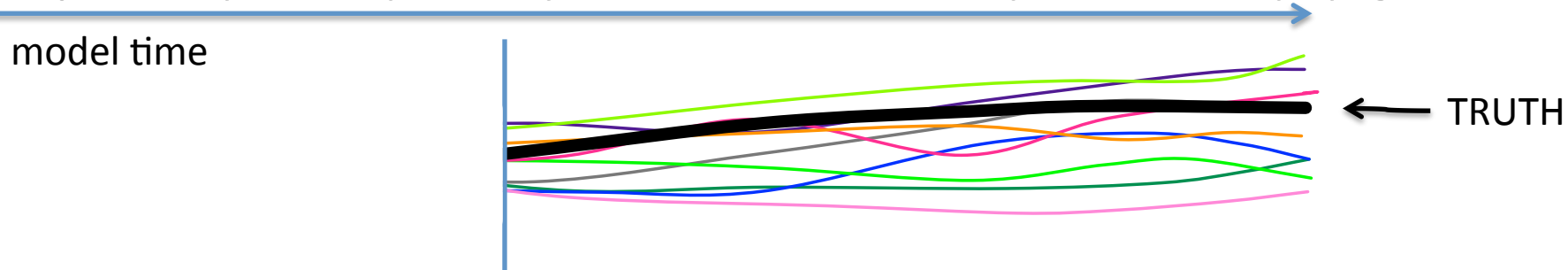
1998-2010
4x daily
is available.

Each POP ensemble member is forced with a different atmospheric reanalysis member.

Generates additional ocean spread.

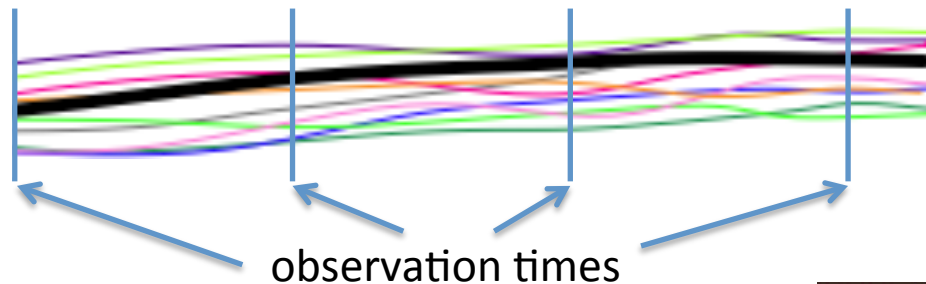
Idealized healthy assimilation diagnostic.

Without Assimilation: each line represents a model trajectory. Frequently, the ensemble spread simply grows.

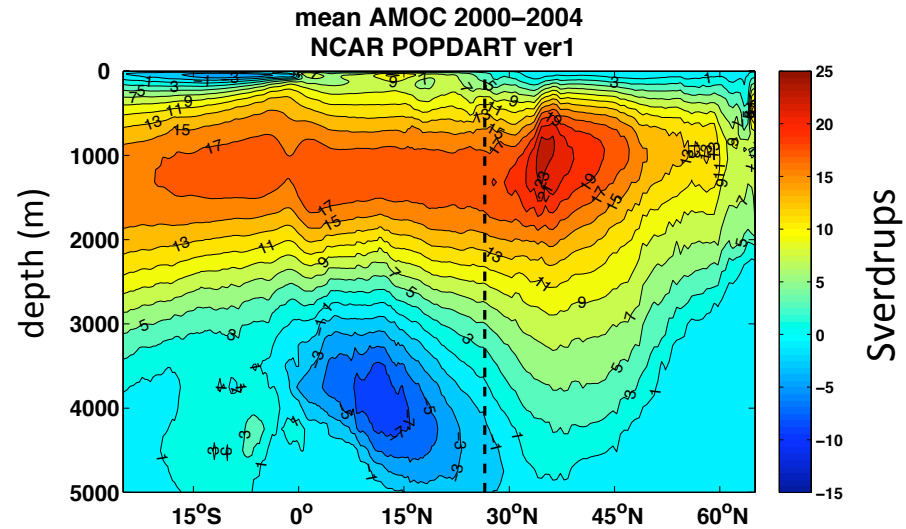
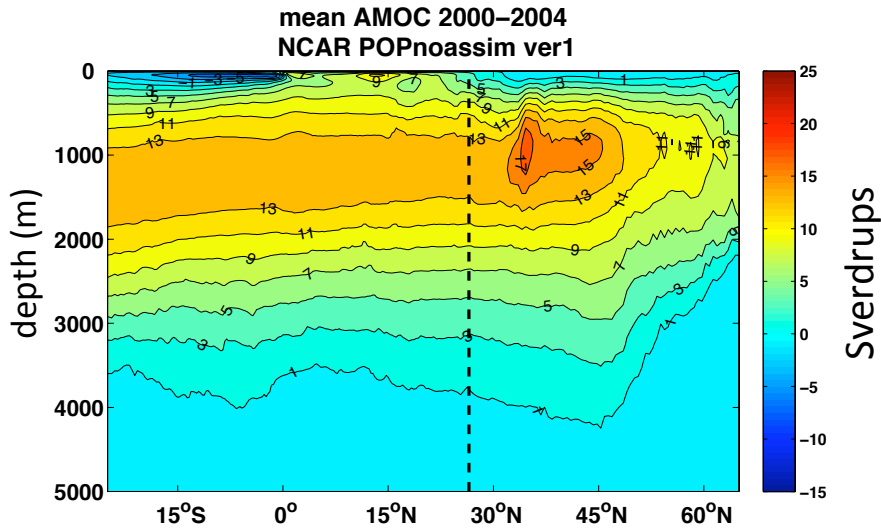


With Assimilation: ensemble spread ultimately remains stable and small enough to be informative, but not so small that it collapses away from the truth.

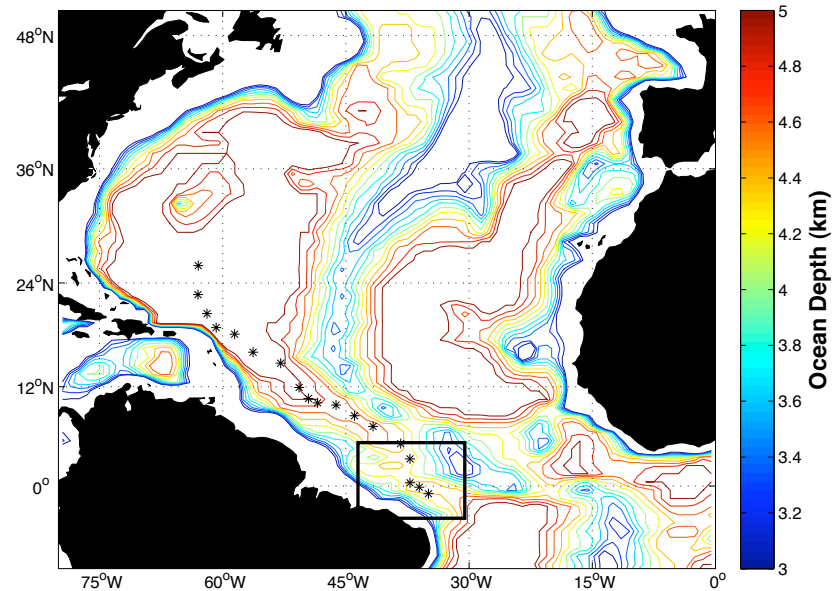
Problem: Getting a proper initial ensemble is an area of active research.



Initialization Issue

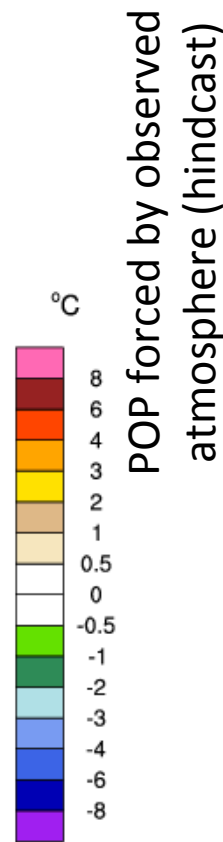
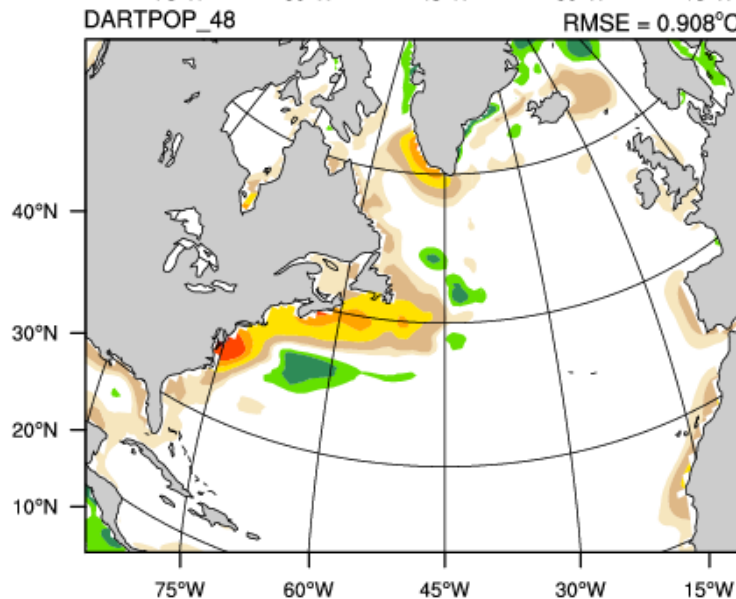
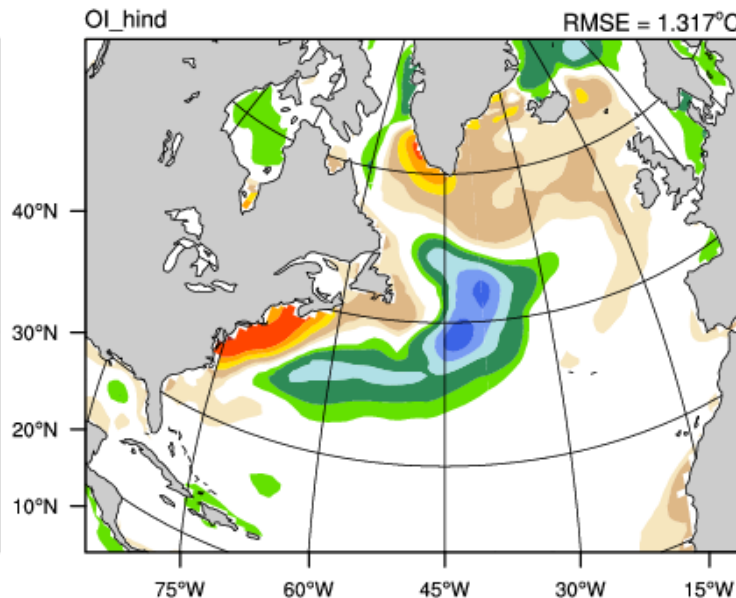
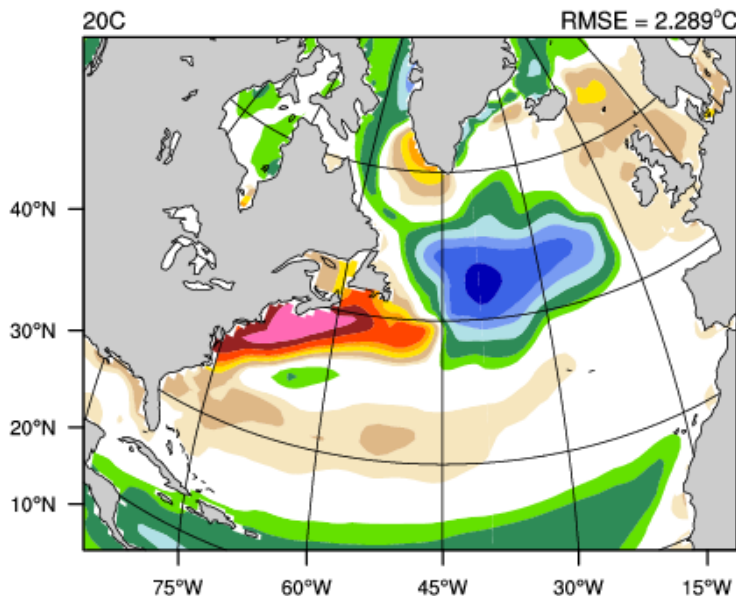


We used 48 January 1st POP ocean states from several different spinup runs with surprising results.



Physical Space: 1998/1999 SST Anomaly from HadOI-SST

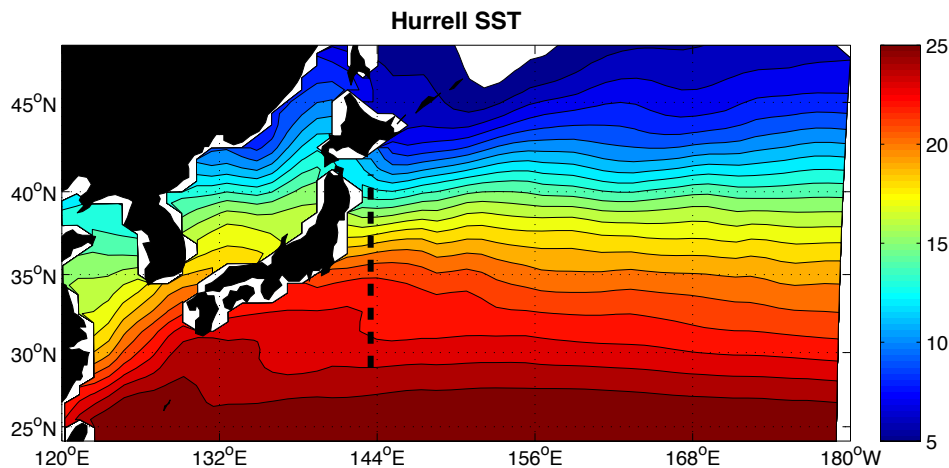
Coupled Free Run



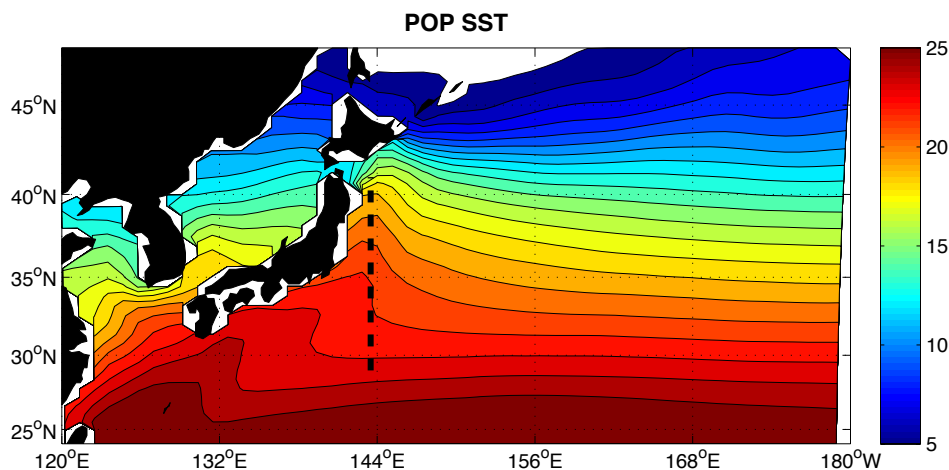
**Ensemble Assimilation
48 POP oceans
Forced by 48 CAM reanalyses**

Challenges where ocean model is unable, or unwilling, to simulate reality.

Example: cross section along Kuroshio; model separates too far north.



Regarded to be accurate.

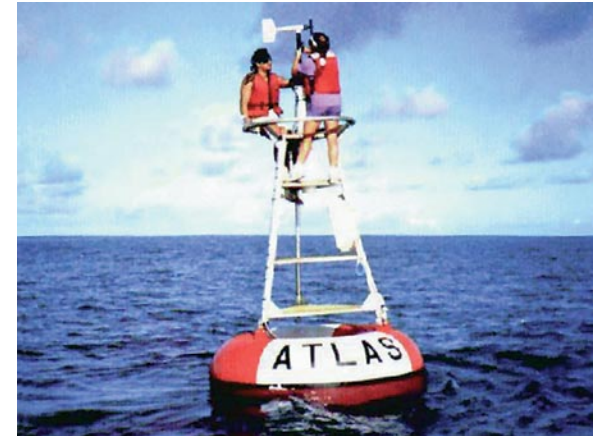


Free run of POP, the warm water is too far North.

World Ocean Database T,S observation counts

These counts are for 1998 & 1999 and are representative.

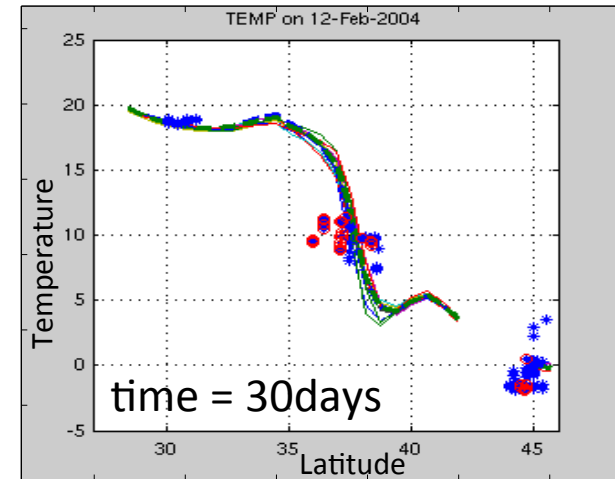
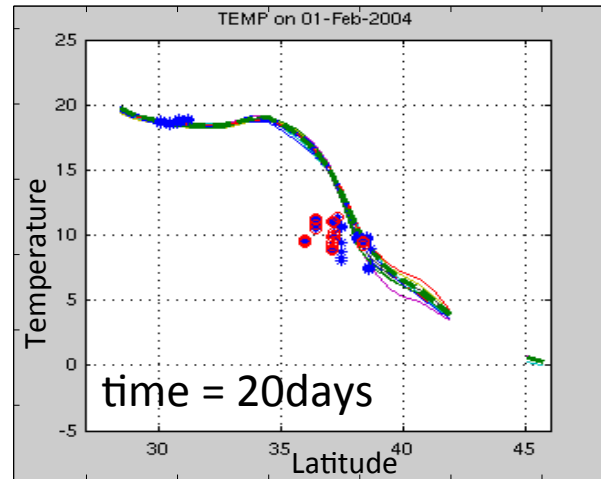
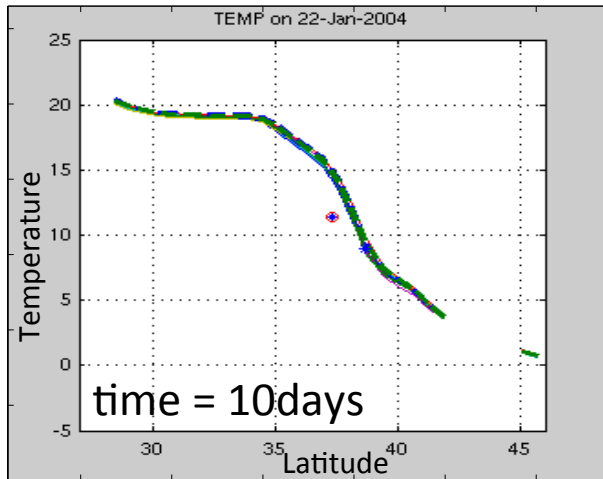
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FLOAT_TEMPERATURE	395032
DRIFTER_TEMPERATURE	33963
MOORING_SALINITY	27476
MOORING_TEMPERATURE	623967
BOTTLE_SALINITY	79855
BOTTLE_TEMPERATURE	81488
CTD_SALINITY	328812
CTD_TEMPERATURE	368715
STD_SALINITY	674
STD_TEMPERATURE	677
XCTD_SALINITY	3328
XCTD_TEMPERATURE	5790
MBT_TEMPERATURE	58206
XBT_TEMPERATURE	1093330
APB_TEMPERATURE	580111



- temperature observation error standard deviation == 0.5 K.
- salinity observation error standard deviation == 0.5 msu.

Challenges in correcting position of Kuroshio.

60-day assimilation starting from model climatology on 1 January 2004.



Initially warm water goes too far north.

Many observations are rejected (red), but others (blue) move temperature gradient south.

Adaptive inflation increases ensemble spread as assimilation struggles to push model towards obs.

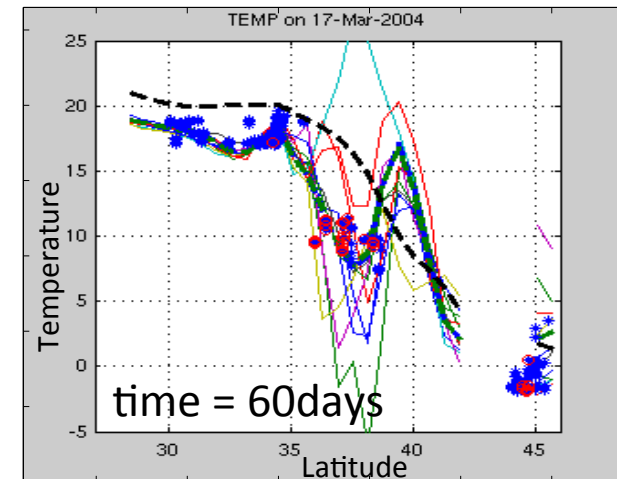
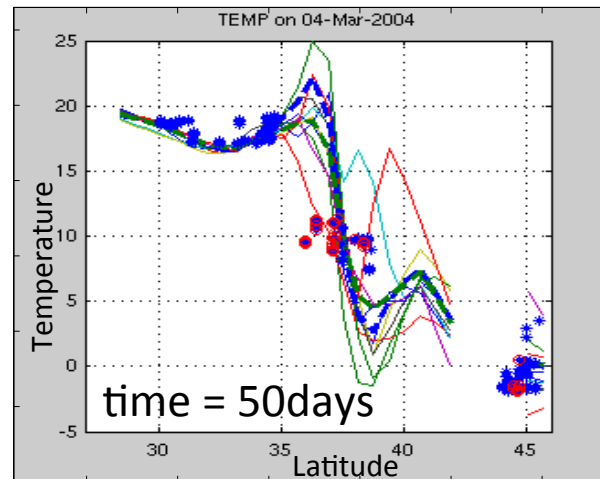
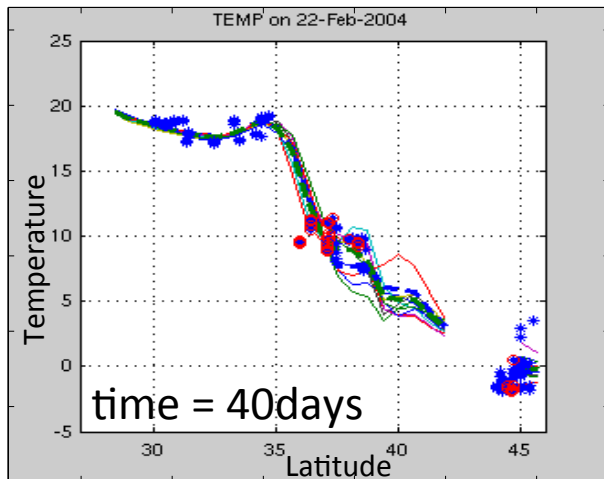
Challenges in correcting position of Kuroshio.

60-day assimilation starting from model climatology on 1 January 2004.

Green dashed line is posterior at previous time,
Blue dashed line is prior at current time,
Ensembles are thin lines.

Observations keep pulling the warm water to the south;
Model forecasts continue to quickly move warm water further north. Inflation continues to increase spread.

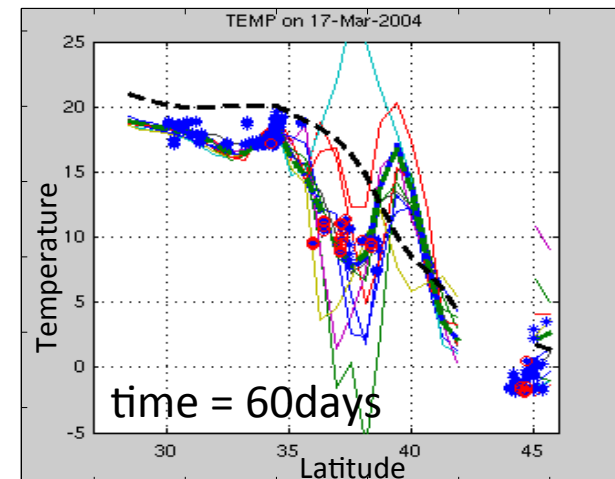
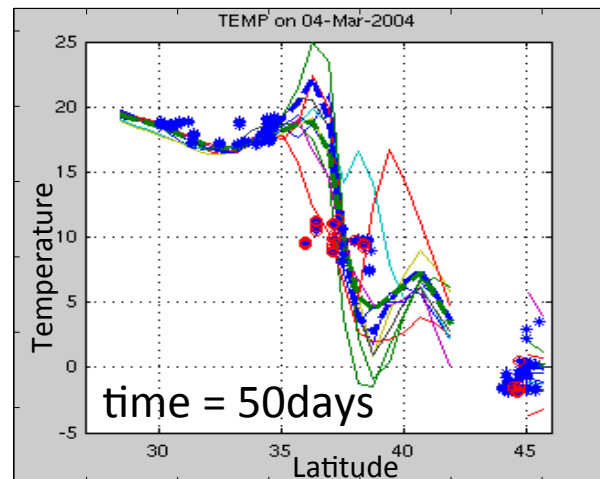
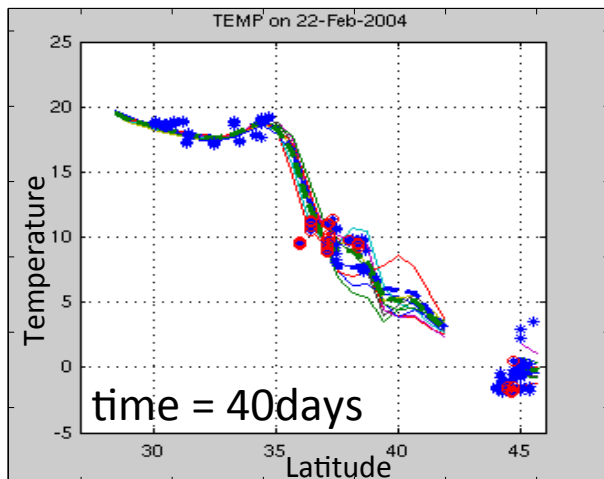
Model forecasts finally fail due to numerical issues. Black dashes show original model state from 10 January.



Challenges in correcting position of Kuroshio.

60-day assimilation starting from model climatology on 1 January 2004.

- Assimilation cannot force model to fit observations.
- Use of adaptive inflation leads to eventual model failure.
- Reduced adaptive inflation can lead to compromise between observations and model.
- Representativeness errors are not all equal Could we adaptively change the error variance based on the model behavior? The same problem happens in the atmosphere – subgridscale winds in tornados, hurricanes ...



Summary

- Properly specifying an initial ensemble is not automatic.
- Forcing each ocean instance with a unique atmosphere helps maintain ensemble spread.
- The observation error for ensemble DA is comprised of instrument error and representativeness.
- The model specification (resolution, etc.) may not be able to exploit the information in the observations.

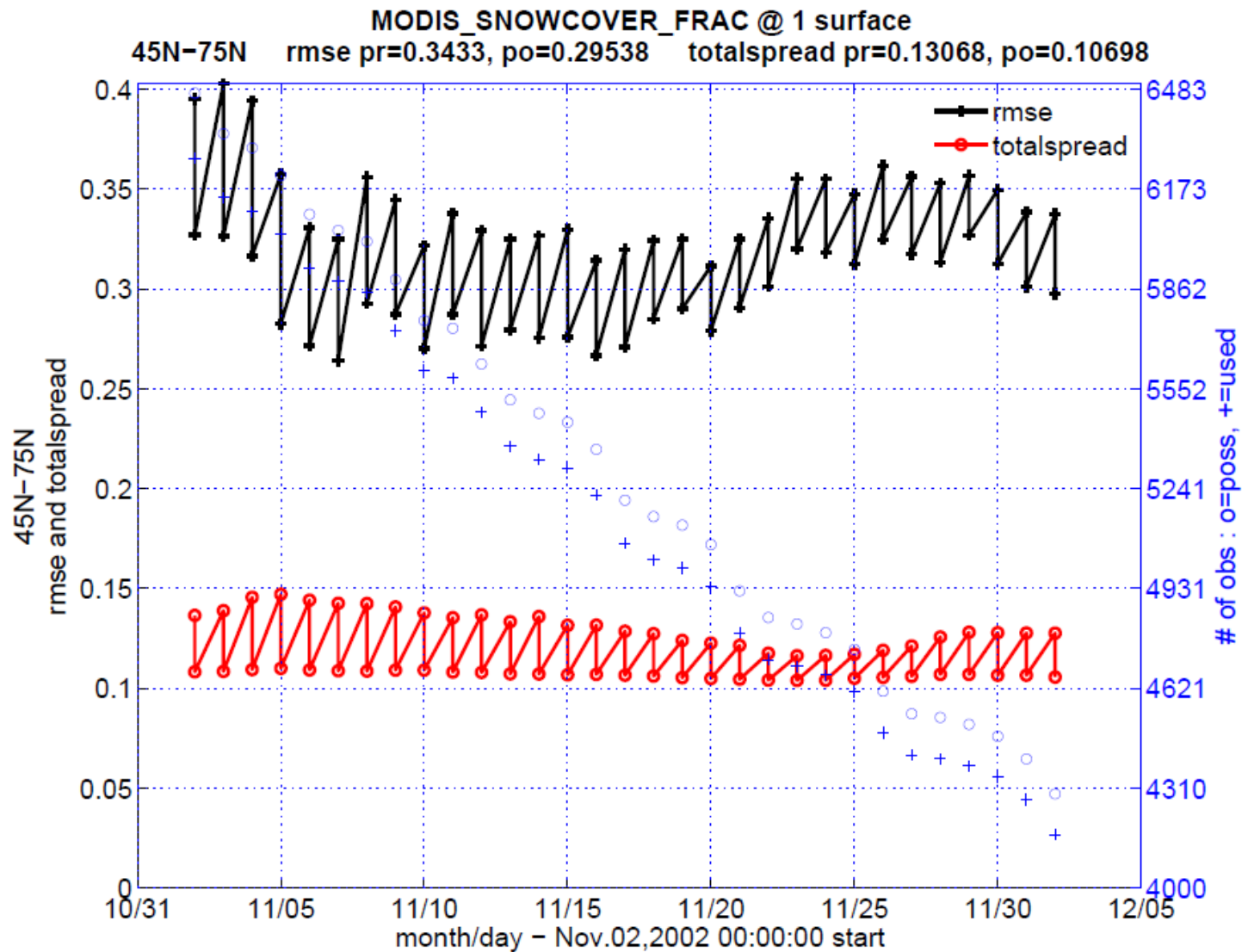
For more information:



www.image.ucar.edu/DARes/DART

dart@ucar.edu

slide held in reserve



slide held in reserve

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MATLAB 7.10.0 (R2010a)
File Edit View Graphics Debug Desktop Window Help
Current Folder: /Users/rhoar/Documents/DART/models/cam/work
Shortcuts: How to Add What's New
Variable Editor - obsmat
Stack: Base 1 | No valid plots for: obsma...
Stackspace:
Name Value Min Max
CopyString prior ensemble...
ObsCopyString NCEP BUFR obs...
ObsTypeString AIRCRAFT_U_W...
ObsQuality co...
dantloc 38 38 38
dantdate /Users/rhoar/D...
dantdir
diag_file ./Prior_Diag.nc
frame /Users/rhoar/D...
mydir /Users/rhoar/D...
obsmat -3768x9 double
obsmat region NaN NaN
truth_file [0,360,-90,90,-1,-1] inf inf
Command Window
link_obs('obs_ensemble_member_3', 'DART quality control', region)
frame = POP11/obs_ensemble_member_3.nc
ObsTypeString = AIRCRAFT_U_WIND_COMPONENT
ObsCopyString = NCEP BUFR observation
CopyString = prior ensemble mean
QCString = DART quality control
region = [0 360 -90 90 -1 -1]
Global obsmat:
link_obs(frame, ObsTypeString, ObsCopyString, QCString, region)
N = 585 RADIOSONDE_SURFACE_ALTITUDE (type 6) tween levels 0.00 and 4588.00
N = 1285 MARINE_SFC_ALTITUDE (type 9) tween levels 0.00 and 195.00
N = 12925 MARINE_SFC_ALTITUDE (type 10) tween levels 122.00 and 4791.00
N = 21840 RADIOSONDE_U_WIND_COMPONENT (type 11) tween levels 360.00 and 103500.00
N = 21846 RADIOSONDE_V_WIND_COMPONENT (type 13) tween levels 360.00 and 103500.00
N = 16870 RADIOSONDE_TEMPERATURE (type 15) tween levels 380.00 and 103500.00
N = 17446 RADIOSONDE_SPECIFIC_HUMIDITY (type 16) tween levels 38000.00 and 103500.00
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N = 1768 AIRCRAFT_V_WIND_COMPONENT (type 20) tween levels 8090.00 and 94210.00
N = 1742 AIRCRAFT_TEMPERATURE (type 21) tween levels 8090.00 and 90820.00
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N = 4078 ACAS_V_WIND_COMPONENT (type 26) tween levels 5530.00 and 103130.00
N = 4084 ACAS_TEMPERATURE (type 27) tween levels 5530.00 and 103130.00
N = 1307 MARINE_SFC_U_WIND_COMPONENT (type 31) tween levels 0.00 and 195.00
N = 1307 MARINE_SFC_V_WIND_COMPONENT (type 32) tween levels 0.00 and 195.00
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N = 1117 MARINE_SFC_SPECIFIC_HUMIDITY (type 34) tween levels 0.00 and 195.00
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N = 18073 SAT_V_WIND_COMPONENT (type 44) tween levels 13700.00 and 92500.00
DART quality control is QC copy 2
DART quality control is QC copy 2
QC summary follows:
(DART quality control == 0) 3412 obs (assimilated)
(DART quality control == 4) 4 obs (prior forward operator failed)
(DART quality control == 6) 31 obs (prior QC rejected)
(DART quality control == 7) 111 obs (outlier rejected)
  
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